IE463 Engineering Economics

Instructor:

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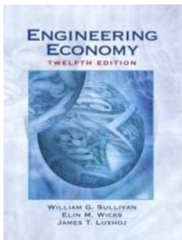
http://web.iku.edu.tr/courses/endustri/eng007/

Course Objectives

- Understand cost concepts and how to make an economic desicion with present economy studies
- Discuss time value of money for personal finance issues
- Learn methods for determining whether an investment project is acceptable (profitable) or not, and how to compare two or more investment alternatives using these methods
- Consider involving income-tax, inflation rate and uncertainty with engineering economy studies
- Finally, develop spreadsheet models as problem solver for engineering economy studies.

Course Materials



Text Book:
W. Sullivan, “Engineering Economy”, Prentice Hall, 2003

Software:
Excel templates for spreadsheet modelling

Lecture notes:
Power point slides (available on course web page)

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Course Topics

Chapter 1:
Cost concepts and present economy studies

Chapter 2:
Time value of money

Chapter 3:
Investmet appraisal (applications of money-time relationships)

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Course Topics

Chapter 4:
Comparing investment and cost alternatives
Chapter 5:
Depreciation and income taxes
Chapter 6:
Price change and inflation rate
Chapter 7:
Dealing with uncertainty

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Grading

- **Exams** (85% of total grade)
  - Quizzes (10%)
  - Midterm I and Midterm II (40%)
  - Final (35%)
- **Assignments** (10% of total grade)
- **Participation** (5% of total grade)

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IE463 – Chapter 1

Cost concepts and present economy studies

COST CONCEPTS

- **Recurring/Nonrecurring Costs -** If costs are repetitive and occur when an organization produces goods or services on a continuing basis, they are "recurring." Otherwise they are "nonrecurring." Variable costs are recurring since they repeat with each unit of output.
- **Direct/Indirect Costs -** If costs can be reasonably measured and allocated to a specific output, they are "direct." Otherwise they are "indirect."

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COST CONCEPTS

- **Overhead Costs -** All costs of providing goods or services other than direct labor and direct material. Indirect costs are a subset of overhead costs. Fixed overhead relates more to plant capacity than production volume (variable overhead). Allocation of overhead to specific outputs may be in proportion to:
  1. Direct labor hours
  2. Direct material costs
  3. Machine hours
- **Cash Cost -** Involves an actual cash payment.
- **Book Cost -** Reflected only in the accounting system.

COST CONCEPTS

- **Sunk Cost -** Past costs that are unrecoverable and are not relevant for decision making purposes.
- Suppose the heating, ventilating and air conditioning (HVAC) system in your home has just experienced a major failure. You immediately call the Air Comfort Company for an estimate to replace your system. Their price is $4,200 and you gladly sign a contract and write a check for the required $1,000 down payment.
- At this point the weather warms and the urgency for replacement of your defunct system eases somewhat.
- You then get a second estimate for a new HVAC system. It is $3,000. You call Air Comfort back and they inform you that the $1,000 down payment is not refundable! What should you do? Explain.

COST CONCEPTS

- **Opportunity Cost -** The cost of forgoing the chance to earn interest (or profit) on investment funds.
- **Question:** "Is it in my best interest to keep my home because it is all paid for? I'm a retired person living with my son, and I have rented my former home, valued at about $185,000, for $400 per month. "
- **Answer:** There is little reason to continue owning your former home as a rental. To see this, consider the opportunity cost, i.e., the return you are giving up, of ownership. The same $185,000 invested in secure Treasury bonds at 7% will provide almost $13,000 in yearly income. This is many times what is obtained from continual rental.

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COST CONCEPTS

- **Life Cycle Cost (LCC) -** LCC are a summation of all the costs (and some revenues) over the entire life span of a structure, or system. All amounts are expressed in dollars that are time-equivalent (the subject of Chapter 3).
- **<u>General Formula:</u>**
  LCC = Investment Costs
  + O&M Costs
  + Replacement Costs
  + Energy Costs
  + Disposal Costs
  – Salvage Value (if any)

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COST CONCEPTS

- **FIXED / VARIABLE COSTS –** If costs change appreciably with fluctuations in business activity, they are "variable." Otherwise, they are "fixed."
- **A widely used cost model is:**
  Total Costs = Fixed Costs + Variable Costs
- **Some examples of fixed costs:** Insurance, taxes on facilities, administrative salaries, rental payments and initial setup or installation.
- **Some examples of variable costs:** direct labor, direct material, unit transportation.

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Example 1.1

- In connection with surfacing a new highway, a contractor has a choice of two sites on which to set up the mixing plant equipment.
- The contractor estimates that it will cost $1.15 per cubic meter per kilometer to haul the asphalt paving material from the mixing plant to the job site.
- If site B is selected, there will be an added charge of $96 per day for a flagman
- The job requires 50,000 cubic meters of mixed asphalt paving material. It is estimated that four months (17 weeks of five working days per week) will be required for the job

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Example 1.1 (continued)

Cost Factors	Site A	Site B
Average hauling distance	6 km	4.3 km
Monthly rental of site	\$1000	\$5000
Cost to setup and remove equipment	\$15000	\$25000
Hauling expense	\$1.15 / m^3/km	\$1.15 / m^3/km

a) Compare the two sites in terms of their fixed, variable, and total costs.

b) For the selected site, how much profit can be made if paid \$8.05 per cubic meter delivered to the job site?

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Example 1.1 (solution to a)

Fixed Costs	Site A	Site B
Monthly rental of site	\$1000 x 4	\$5000 x 4
Cost to setup and remove equipment	\$15,000	\$25,000
Flagman wage	0	\$96 x 85
Total Fixed Costs	**\$19,000**	**\$53,160**
Variable Costs	**Site A**	**Site B**
Hauling expense	\$1.15 / m^3/km x 6 km x 50,000 m^3 = **\$345,000**	\$1.15 / m^3/km x 4.3 km x 50,000 m^3 = **\$247,250**
Total Costs	**Site A**	**Site B**
Fixed + Variable	**\$364,000**	**\$300,410**

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Example 1.1 (solution to b)

PROFIT = REVENUE – TOTAL COST

REVENUE = $8.05 / m^3 (50,000 m^3) = $402,500

PROFIT = $402,500 – $300,410 = $102,090

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Example 1.2

Consider the following cost and production data and develop cost estimating relationship (CER) equation between produced units and total cost, and estimate the cost for production capacity of 2100 units.

Month	1	2	3	4	5	6	7
Produced units	1000	850	1500	900	450	690	1150
Total cost	7000	6550	8500	6700	5350	6070	7450

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Least Squares Normal Equations

$y = a + bx \longrightarrow CER$

y = total cost a = fixed cost

x = produced units b = unit variable cost

$$b = \frac{n\sum_{i=1}^{n} x_i y_i - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2} \qquad a = \frac{\sum_{i=1}^{n} y_i - b\left(\sum_{i=1}^{n} x_i\right)}{n}$$

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Example 1.2 (solution)

$n = 7$

$$\sum_{i=1}^{n} x_i = 6540,\ \sum_{i=1}^{n} y_i = 47{,}620,\ \sum_{i=1}^{n} x_i^2 = 6{,}783{,}600,\ \sum_{i=1}^{n} x_i y_i = 46{,}510{,}800.$$

$$b = \frac{7(46{,}510{,}800) - (6540)(47{,}620)}{7(6{,}783{,}600) - (6540)^2} = 3$$

$$a = \frac{(47{,}620) - 3(6540)}{7} = 4000$$

$y = 4000 + 3x$

x (production) = 2100 units

y (total cost) = \$4000 + (\$3 /unit)(2100 units) = \$10,300

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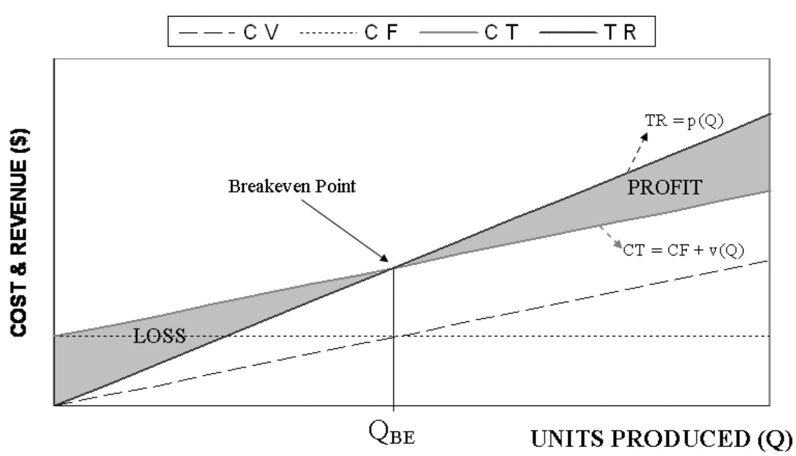
BREAKEVEN ANALYSIS

Notation

TR = Total Revenue
CT = Total Cost
CF = Fixed Cost
CV = Varaible Cost
v = Unit Variable Cost per unit
p = Price per unit
Q = Demand (output rate)

BREAKEVEN ANALYSIS



BREAKEVEN ANALYSIS

at BREAKEVEN point (Q_{BE}), TR = CT,
so NO LOSS & NO PROFIT

$$p(Q) = CF + v(Q),$$

$$Q_{BE} = \frac{CF}{p - v} \quad , \qquad \text{for } p > v.$$

if DEMAND (Q) > Q_{BE}, then PROFIT
if DEMAND (Q) < Q_{BE}, then LOSS

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Example 1.3

An engineering consulting firm measures its output in a standard service hour unit. The variable cost (v) is \$62 per standard service hour. The charge-out rate (i.e., selling price "p") is 1.38v = \$85.56 per hour. The maximum output of the firm is 160,000 hours per year, and its fixed cost (CF) is \$2,024,000 per year. For this firm,

a) What is the breakeven point in standard service hours and in percentage of total capacity?
b) What is the percentage reduction in the breakeven point (sensitivity) if fixed costs are reduced 10%?

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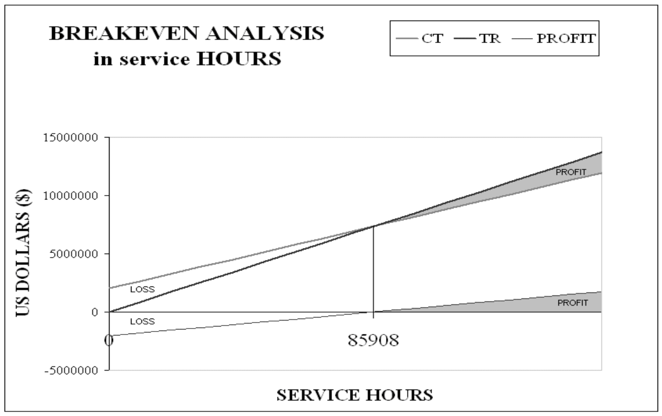
Example 1.3 (solution to a)

$$Q_{BE} = \frac{CF}{p - v} = \frac{\$2{,}024{,}000}{\$85.56\ /\ hour\ -\ \$62\ /\ hour} = 85{,}908\ hours$$



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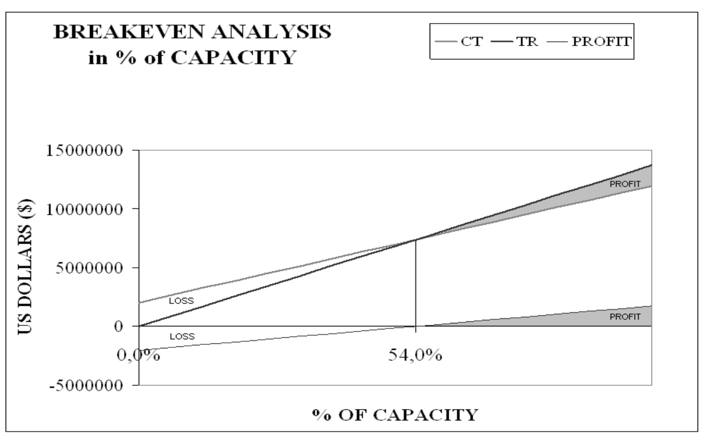
Example 1.3 (solution to a)

$$Q_{BE}\% = \frac{Q_{BE}}{total\ CAPACITY} = \frac{85{,}908\ hours}{160{,}000\ hours} = 0.54 = 54\%\ \ of\ total\ CAPACITY$$



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Example 1.3 (solution to a)

if CF is reduced by 10%, $newQ_{BE} = ?$ and $(Q_{BE} - newQ_{BE}) / Q_{BE} = ?$
$reduced\ CF = CF\ (1 - 0.1) = \$2{,}024{,}000\ (0.9) = \$1{,}821{,}600$

$$newQ_{BE} = \frac{reduced\ CF}{p - v} = \frac{\$1{,}821{,}600}{\$85.56\ /\ hour\ -\ \$62\ /\ hour} = 77{,}318\ hours$$

$$\%\ reduction\ in\ Q_{BE} = \frac{Q_{BE} - newQ_{BE}}{Q_{BE}} = \frac{85{,}908\ hrs - 77{,}318\ hrs}{85{,}908\ hrs} = 10\%$$

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Example 1.4

Consider the example 1.1 in which the following costs are related to two alternatives, site A and site B. What is the BREAKEVEN quantity of mixed asphalt at which SITES A and B are indifferent?

Costs	**Site A**	**Site B**
Fixed Cost	\$19000	\$53160
Unit variable cost	\$6.9/m^3	\$4.95/m^3

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Example 1.4 (solution)

$$CT_A = CT_B$$

$$CF_A + v_A Q = CF_B + v_B Q$$

$$19{,}000 + 6.9\ Q\ = 53{,}160 + 4.95\ Q$$

Q : quantity of mixed asphalt (m^3)

$$Q_{BE} = \frac{CF_B - CF_A}{v_A - v_B} = \frac{\$53{,}160 - \$19{,}000}{\$6.9/m^3\ -\ \$4.95/m^3} = 17{,}518\, m^3$$

for $CF_B > CF_A$ and $v_A > v_B$

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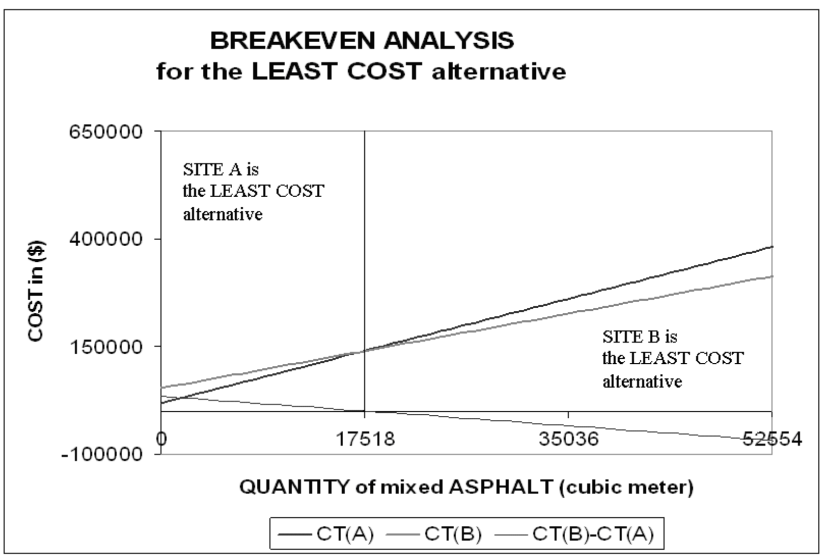
Example 1.4 (solution)



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Example 1.5

Three project alternatives are considered as an investment opportunity, their cost figures are provided in the following table.

a) Calculate the breakeven point for each pair of alternatives
b) Show their cost comparison on a graph
c) For the expected output rate of 10,000 units in the considered period, which alternative would you prefer? And what is the selling price per unit to make $10,000 profit in that period?

Cost figures	A	B	C
Fixed cost	$100,000	120,000	150,000
Unit variable cost	15 $/unit	12	10

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Example 1.5 (solution to a)

<u>Pairs of alternatives:</u>

$i.\ CT_A = CT_B$

$ii.\ CT_B = CT_C$

$iii. CT_A = CT_C$

$i.\ CT_A = CT_B \qquad \text{for } CF_B > CF_A \text{ and } v_A > v_B$

$$Q_{BE}^{A-B} = \frac{CF_B - CF_A}{v_A - v_B} = \frac{\$120{,}000 - \$100{,}000}{\$15/unit - \$12/unit} = 6667\ units$$

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Example 1.5 (solution to a)

$CT_A = CT_C \quad$ for $CF_C > CF_A$ and $v_A > v_C$

$$Q_{BE}^{A-C} = \frac{CF_C - CF_A}{v_A - v_C} = \frac{\$150{,}000 - \$100{,}000}{\$15/unit - \$10/unit} = 10{,}000\ units$$

$CT_B = CT_C \quad$ for $CF_C > CF_B$ and $v_B > v_C$

$$Q_{BE}^{B-C} = \frac{CF_C - CF_B}{v_B - v_C} = \frac{\$150{,}000 - \$120{,}000}{\$12/unit - \$10/unit} = 15{,}000\ units$$

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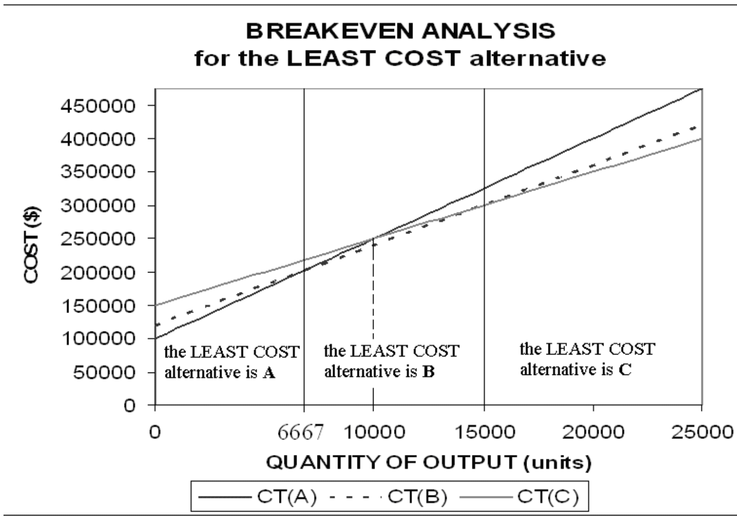
Example 1.5 (solution to b)



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Interpretation of the graph

if $Q < 6667$ units, A is the least cost
if $6667 < Q < 15{,}000$ units, B is the least cost
if $Q > 15{,}000$ units, C is the least cost

Q = QUANTITY of output (units) = $10{,}000$ units

So, alternative B is PREFERRED !

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Example 1.5 (solution to c)

$PROFIT = \$10{,}000$ at $Q = 10{,}000$ units (sales volume)
$TR = p\,Q = p10{,}000$

$$CT_B = CF_B + v_B\,Q = 120{,}000 + 12(10{,}000) = \$240{,}000$$

$$PROFIT = TR - CT \rightarrow 10{,}000 = p10{,}000 - 240{,}000$$

$$PRICE = \$\,p\,/\,unit = \frac{PROFIT + CT_B}{Q} = \frac{\$10{,}000 + \$240{,}000}{10{,}000\ units} = \$25\,/\,unit$$

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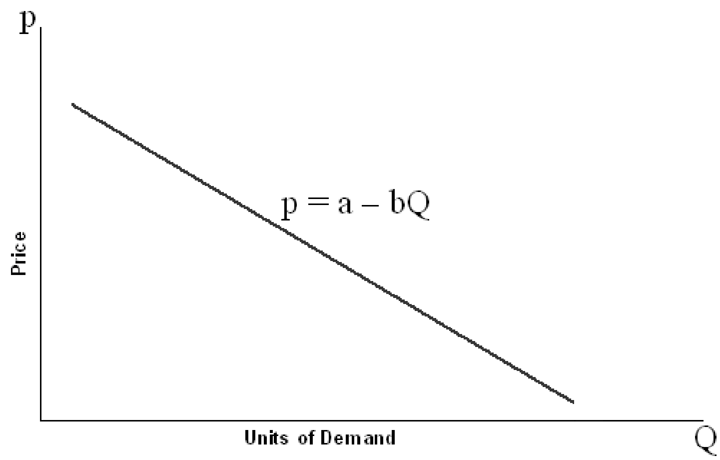
The General Price-Demand Relationship



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The General Price-Demand Relationship

The relationship between price and demand can be expressed as a linear function:

$$Q = a/b - p(1/b) = (a - p) / b$$

or

$$p = a - bQ \text{ for } 0 \le Q \le a / b, \text{ and } a>0, \; b>0$$

where

p = price per unit

Q = demand for the product or service (# of units)

a = base (maximum) price (intercept on the price axis)

b = slope of the price-Demand line

$1/b$ = amount by which demand increases for each unit decrease in price

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The Total Revenue Function

TR = (price per unit) x (demand) = pQ

$TR = (a - bQ)Q = aQ - bQ^2$ for $0 \leq Q \leq a / b$

where
p = price per unit
Q = demand for the product or service (# of units)
a = base (maximum) price (intercept on the price axis)
b = slope of the price-Demand line

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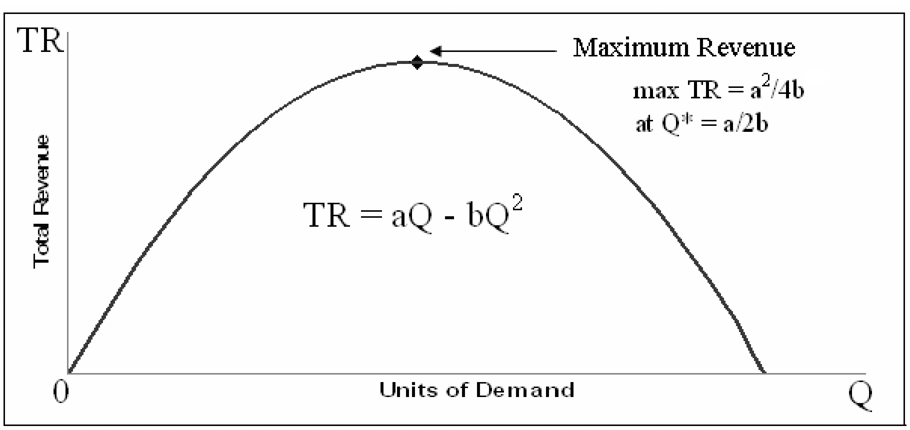
The Total Revenue Function



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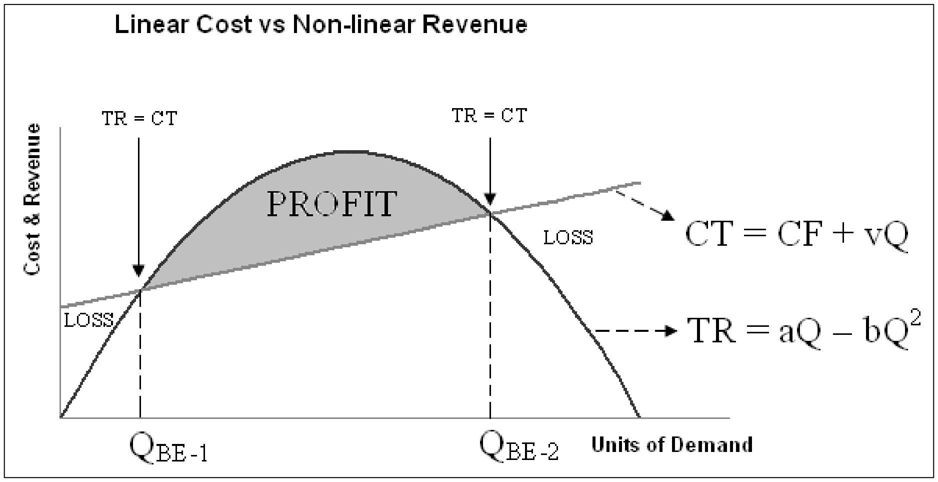
Nonlinear Breakeven Analysis



Profitable Domain ➔ $Q_{BE\text{-}1} < Q(demand) < Q_{BE\text{-}2}$

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Breakeven Points

$$TR = CT \Rightarrow TR - CT = 0$$

$$TR = aQ - bQ^2 \text{ and } CT = CF + vQ$$

$$-bQ^2 + (a - v)Q - CF = 0$$

$$Q_{BE-1,2} = \frac{-(a-v) \pm \sqrt{(a-v)^2 - 4(-b)(-CF)}}{2(-b)}$$

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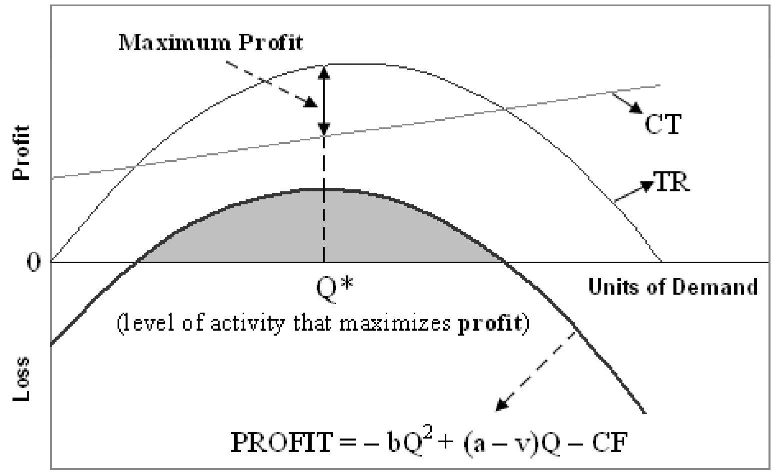
Profit Function

PROFIT = TR – CT = $-bQ^2 + (a - v)Q - CF$

for $0 \le Q \le a/b$, and $a>0$, $b>0$



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Optimal Production Quantity

PROFIT = TR – CT = $-bQ^2 + (a - v)Q - CF$

$$\frac{d(PROFIT)}{dQ} = 0 \quad \Rightarrow \quad -2bQ + (a - v) = 0$$

$$Q^* = \frac{(a - v)}{2b}$$

$$\frac{d^2(PROFIT)}{dQdQ} < 0 \quad \Rightarrow \quad -2b < 0, \quad for\ b > 0$$

It proves that Q^* maximizes profit

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Example 1.6

A company produces an electronic timing switch that is used in consumer and commercial products made by several other manufacturing firms. The fixed cost (CF) is $\$73{,}000$ per month, and the variable cost (v) is \$83 per unit. The selling price per unit is $p = \$180 - 0.02Q$. For this situation;

a) Find the volumes at which breakeven occurs; that is, what is the domain of profitable demand?
b) Determine the optimal volume for this product in order to maximize profit.
c) What is the maximum profit per month at the optimal volume?

Example 1.6 (solution to a)

$$TR = CT \;\; or \; Profit = 0$$

$$Profit = TR - CT = pQ - CF - vQ = 0$$

$$Profit = (180 - 0.02Q)Q - 73{,}000 - 83Q = 0$$

$$-0.02Q^2 + (180 - 83)\,Q - 73{,}000 = 0$$

$$Q_{BE-1} = \frac{-97 + \sqrt{(97)^2 - 4(-0.02)(-73{,}000)}}{2(-0.02)} = 932 \; units \,/\, month$$

$$Q_{BE-2} = \frac{-97 - \sqrt{(97)^2 - 4(-0.02)(-73{,}000)}}{2(-0.02)} = 3{,}918 \; units \,/\, month$$

The domain of profitable demand per month = *932* units to *3,918* units

Example 1.6 (solution to b)

$$Profit = (180 - 0.02Q)Q - 73{,}000 - 83Q$$
$$Profit = -0.02Q^2 + (180 - 83)\ Q - 73{,}000$$

Take first derivative and set = 0

$$dProfit / dQ = 0 \quad \Rightarrow \quad -0.04Q + 97 = 0$$

Q* = 2,425 units /month *(# of products that maximizes profit)*

$$d^2Profit / dQdQ = -0.04 < 0$$

It proves that Q^* maximizes profit

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Example 1.6 (solution to c)

Use equation for profit and $Q^* = 2{,}425$ units /month,

$$Profit = (180 - 0.02Q)Q - 73{,}000 - 83Q$$
$$Profit = -0.02Q2 + (180 - 83)\ Q - 73{,}000$$

Maximum $Profit = -0.02(2{,}425)2 + (97)(2{,}425) - 73{,}000$

Maximum *Profit = \$44,612 /month*

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